Mission Planning for Employing Internet Protocol (IP) on the Local Ionospheric Measurements Satellite (LionSat)

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LionSat

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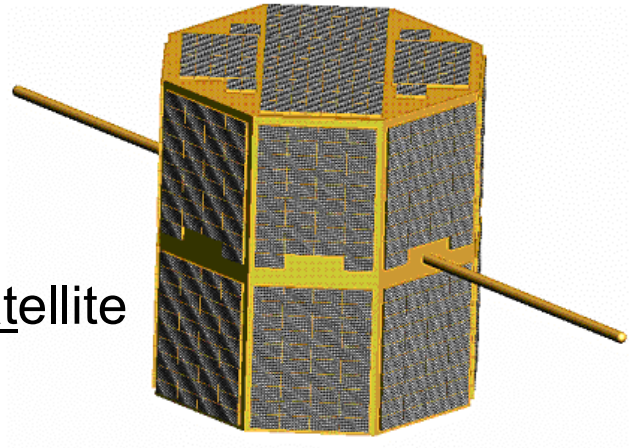
LionSat Overview



LionSat

- Local Ionospheric Measurements Satellite
  - Funded by Nanosat program sponsored by AFOSR/NASA/AIAA
- Scientific goals
  - Explore ram/wake structure via probes as spacecraft “rolls” along orbit
  - Obtain ambient measurements of undisturbed ionospheric plasma environment via two probes mounted on deployed booms
  - Correlate ambient to ram/wake measurements
- Engineering goal
  - Investigate initial spin-up and spin maintenance using pair of RF ion microthrusters
- Educational goals
  - Prepare students at undergraduate and graduate levels for productive careers in technical and nontechnical fields relating to space systems

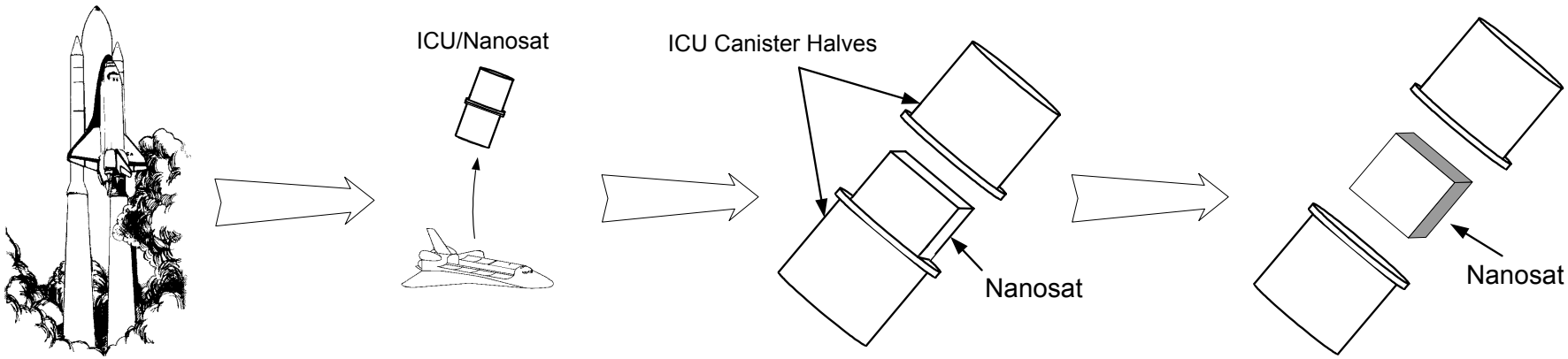
University Nanosat-3 Program

- NS-3 Objectives
  - Future workforce training through national student satellite design and fabrication competition
  - Development of small satellite technology area, including subsystems development and standard deployment systems with rapid launch capability at low cost
- NS-3 Description
  - Satellite design and fabrication competition to be sponsored by AIAA (recurring 2-yr cycle)
    - Winner of competition is launched from Space Shuttle (baseline)
  - AFRL/VS–STP will develop second generation small satellite launch adapter that provides significant safety-related protections
  - AFRL/VS–NASA GSFC will develop suite of standard nanosat components (bus, power, comm, etc.)
  - NASA GSFC will provide design and safety related guidance to participating universities
  - AFOSR to provide *nominal* funding to US universities to participate in competition

NS-3 User's Guide Deployment Concept

LionSat

- Baseline is Shuttle launch using STP Canister for all Payload Ejections (CAPE) deployment system
- Nanosat will be mounted inside AFRL Internal Cargo Unit (ICU)
- ICU/Nanosat is installed inside CAPE canister
- ICU/Nanosat is ejected from CAPE on orbit
- ICU halves separate and Nanosat is released



1. Launch
2. ICU/Nanosat Deployment from Orbiter
3. ICU Separation
4. Nanosat Separation

LionSat Schedule

- AO released in November 2002 – three week response
- Award notification received just before Christmas 2002
  - 13–14 awards were made
- Converted class participation at start of the spring semester
- System Concept Review – April 2003
- Preliminary Design Review – August 2003
- Critical Design Review – August 2004
- Flight Competition Review – in January 2005
- Launch around March 2006

Science Data Rate

- Roll rate of ~10 rpm
  → 14,400 rolls/day
- 12 samples per roll
  × 4 sensor heads
  → 691,200 samples/day

Mode	Bytes/sample
Swept Plasma Freq P	1024
Swept Bias LP	512
Tracking Plasma Freq	6
Fast Temperature P	4
Fixed Bias LP	2

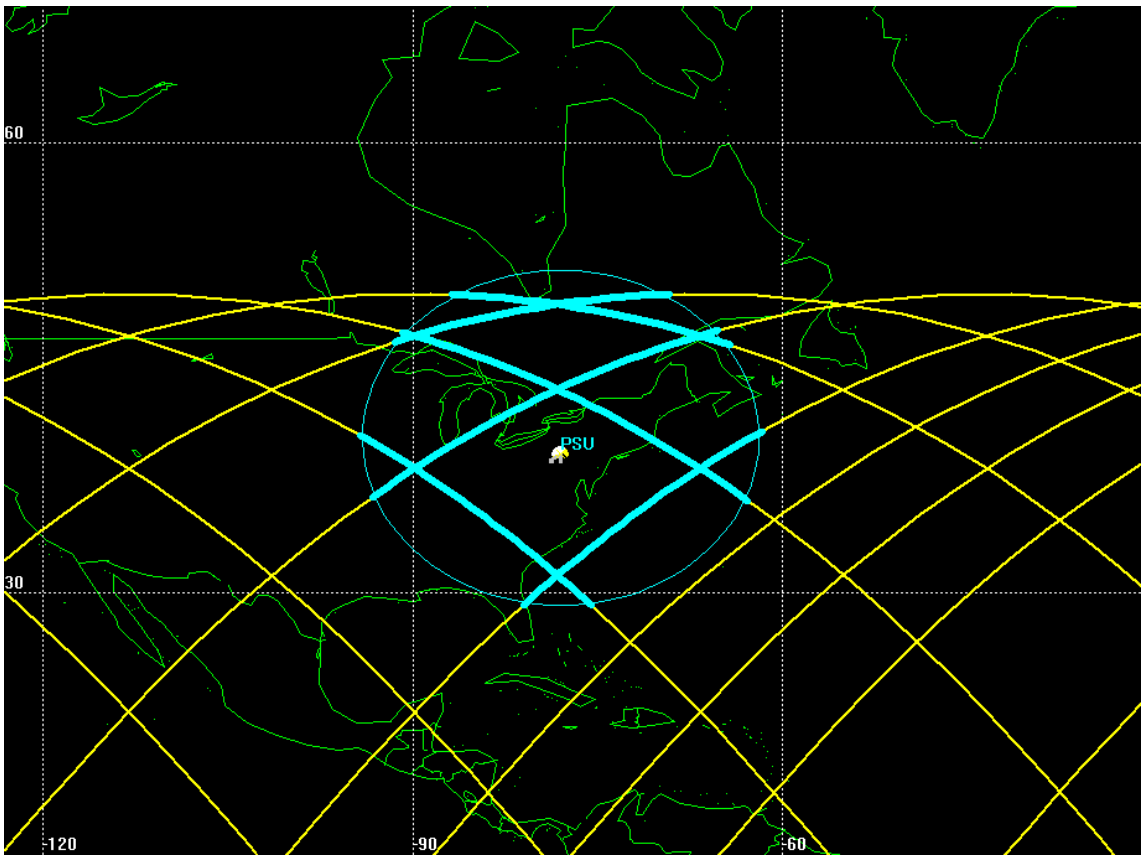
Functional Objective	Swept Plas. FP	Swept Bias LP	Tracking Plas. FP	Fast Temp. P	Fixed Bias LP	Portion of day	MB/day
1	5%	10%	40%	10%	40%	15%	11.0
2	100	0	0	0	0	1.5	10.6
3	0	20	40	10	40	15	11.0
4	0	2.5	0	0	97.5	100	10.2

Total Data Rate

- Science: Functional Objective dependent
  = 11.0 MB/day
- Magnetometer: (for science and attitude)
  - 6 B/sample • 172,800 samples/day = 1.04 MB/day
- GPS: (for orbit determination and time)
  - 20 B/sample • 0.1 samples/second = 0.17 MB/day
- Housekeeping:
  - 6 temp, 40 voltage, 10 current, 2 tank pressure, and 3 horiz. sens.
  - 2 B/sample/ch. • 61 ch's • 0.1 samples/second = 1.05 MB/day
- Total: 13.3 MB/day to download

LionSat Orbital Parameters

LionSat



- Launched into LEO orbit from Shuttle
- 51° inclination
- ~400 km altitude
- ~6 mo → 1 yr lifetime

LionSat Link Characteristics

- ~Six sequential overpasses/day
- Reacquisition needed for each pass
- Maximum path length 1470 – 1840 km
  → maximum t_{delay} ~ 4.9 – 6.1 ms
- Data generated on satellite, asymmetric link
- LionSat initializes handshake based on GPS and ephemeris data
  - If no response, LionSat broadcasts in the blind

Transmission Data Rate

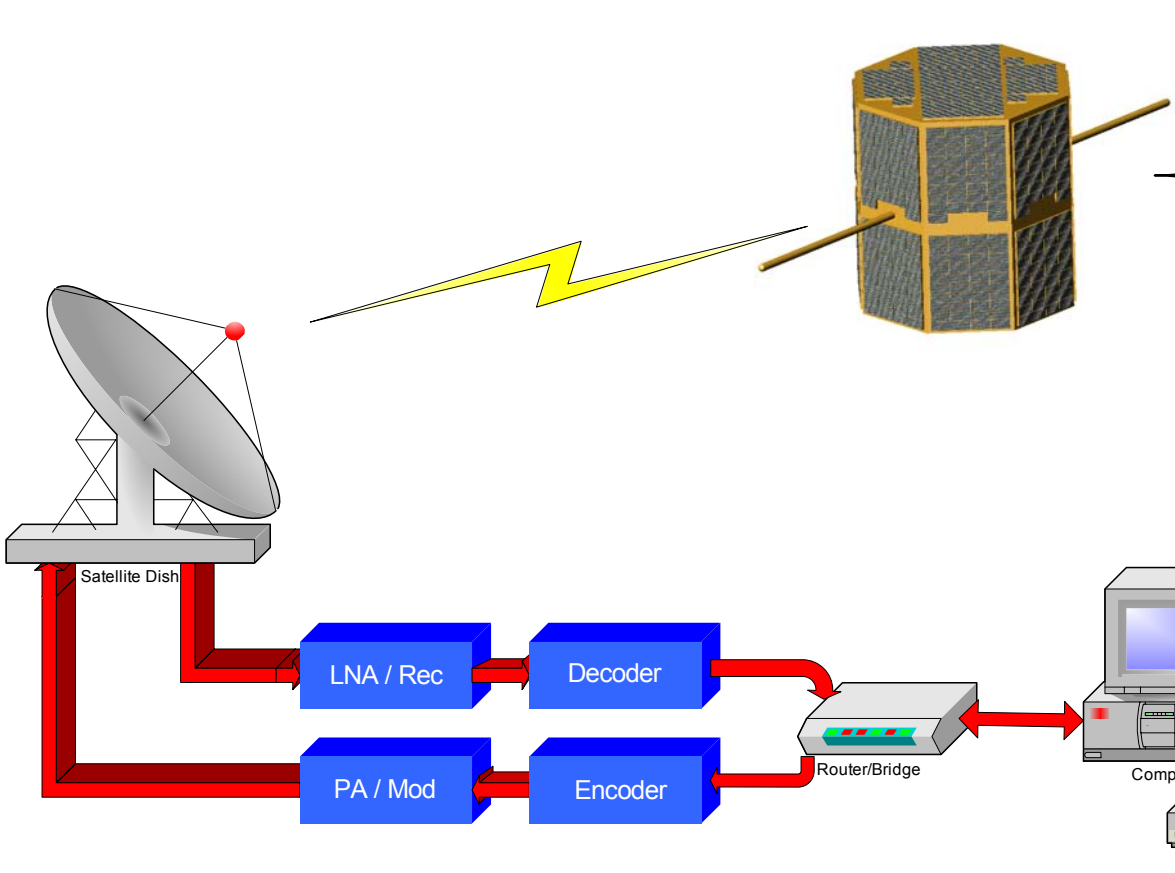
- Minimum elevation angle and overhead dependent

	10 deg min elevation		5 deg min elevation	
	directly centered	not centered	directly centered	not centered
Total bytes per day to receive	13253760	13253760	13253760	13253760
Avail. download time (sec/day)	1667	1882	2750	2921
= raw data rate (Bytes/sec)	7951	7042	4820	4537
= raw data rate (bits/sec)	63605	56339	38556	36299
Divide by IP in Space efficiency	0.85	0.85	0.85	0.85
= processed data rate (bits/sec)	74830	66281	45360	42705
* 1.2 for design margin (bits/sec)	89796	79537	54433	51246
rate 1/2 convolution encoding	179592	159075	108865	102492

- Baseline design: 200 kb/sec

LionSat Communications Component View

LionSat



Why Use IP?

- Allows for easier integration of multiple ground stations
  - NS-3 participants may share ground stations
  - AFRL/NASA may provide access
- COTS hardware/software for low-budget program
- Student experience will be in standard protocols not specialized, narrow discipline
  - More relevance to students' professional development
  - More likely to find students with expertise

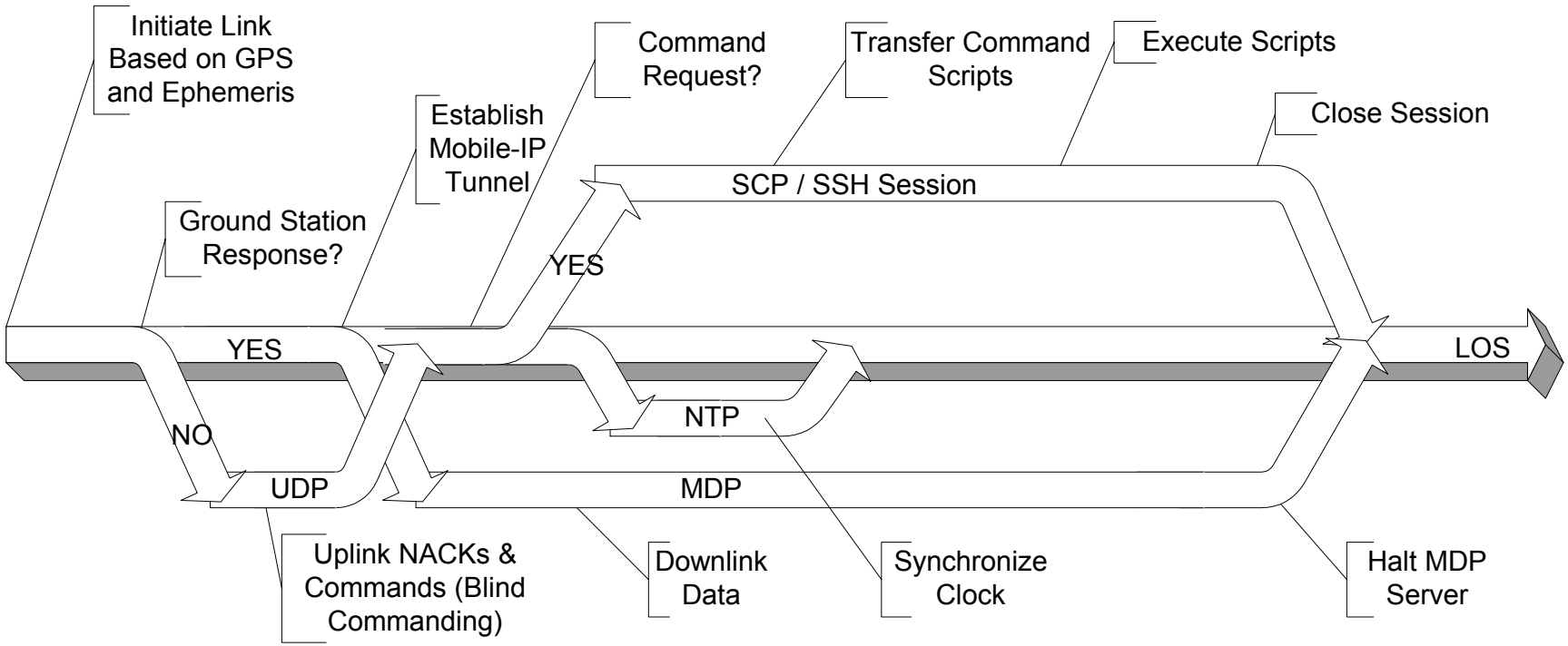
CPU Development Kit Capabilities

LionSat

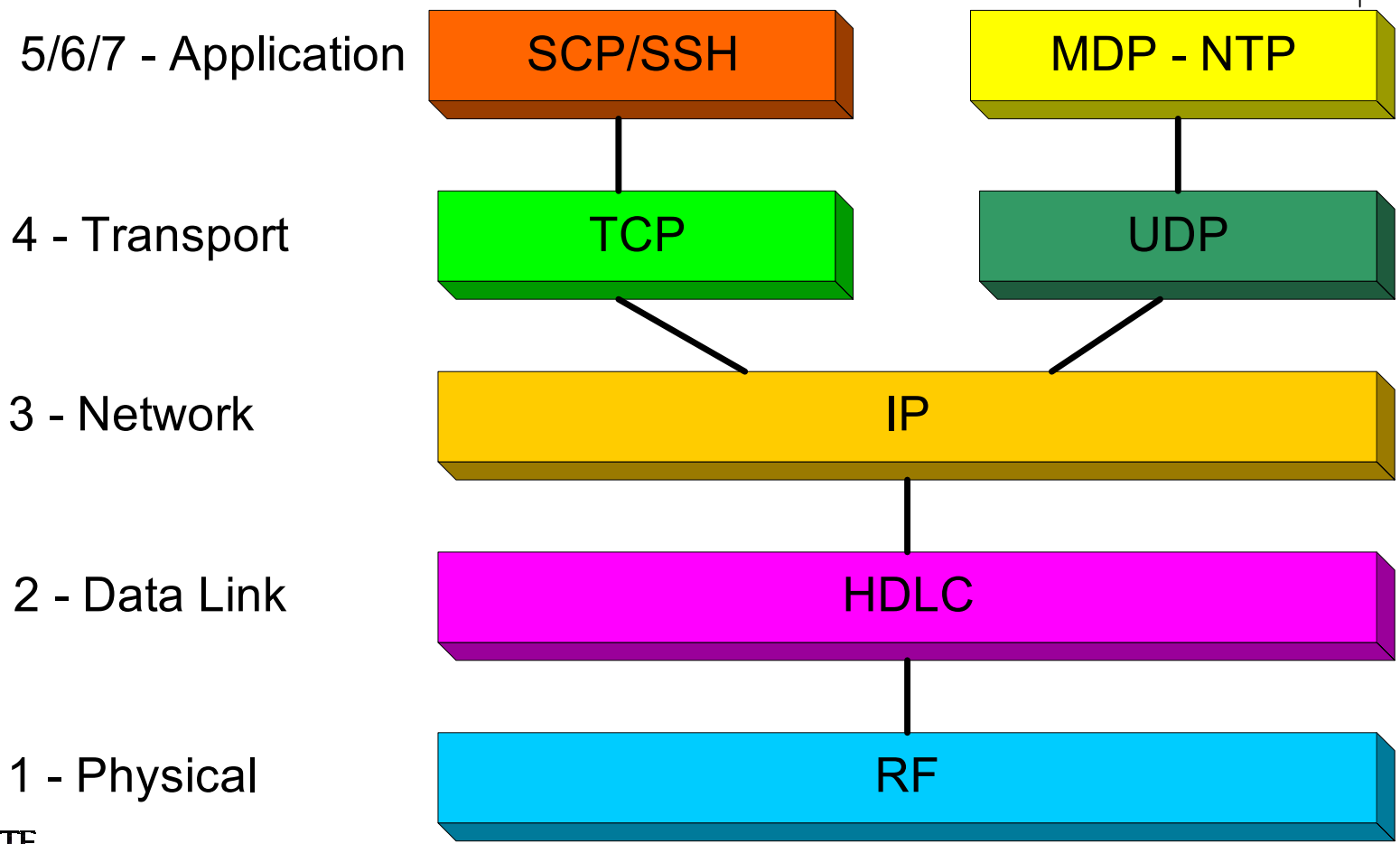
- Intel SA1110, 32MB SDRAM/16MB flash
- Serial/ethernet links
- Linux based on 2.4 kernel
- In-system programmable
- Embedded TCP/IP stack
- FTP server
- Web server
- Kernel/root file system packages + compiler
- Teraterm Pro + Netspy included
- Massive documentation + code examples
- Development on Linux/Windows PC

SSV DNP/1110
High-speed DIL/NetPC

LionSat Communications Timeline View



LionSat Communications Layer View



UDP in Space

- UDP is efficient in the blind
  - No connection setup overhead
  - No ACK overhead
  - Less protocol overhead
- UDP provides one way transport
  - MDP – reliable file transfer protocol
  - RTP – real-time system status display

Security Issues

- Host-based security
  - Only run SSH on satellite
  - RSA-based login
  - Keys stored offline on ground station
- Require IPSec to talk to satellite
  - Authentication headers
    - Ensures only ground station can talk to LionSat

LionSat & The OMNI Project

- OMNI has developed and successfully flown full IP over HDLC missions – UoSat-12, CHIPSat, STS-107/CANDOS
- OMNI has demonstrated IP through NASA's TDRSS
- OMNI has extensive experience implementing effective, low-cost IP communication architectures for space applications
- OMNI has existing code & applications to support future missions with limited adaptation/porting required

- OMNI will provide advice and "mentoring" to Penn State University students in developing and implementing the LionSat mission model and flight software

OMNI
Operating Missions as Nodes on the Internet

CSC

PENNSTATE

NASA

AIAA American Institute of Aeronautics and Astronautics

Test-Bed Opportunities

- LionSat will use IP communications for return of prime science data and uploading new campaign scenarios
- After basic mission criteria have been met, LionSat can be used as a test-bed for testing/verifying relative performance of various protocols

Summary

- LionSat part of Nanosat-3 program and will provide ionospheric measurements and test new microthruster
- LionSat is excellent educational experience for students
- Partnership with GSFC/OMNI for mentoring student satellite team
- LionSat will use IP communications to download data and upload new campaigns
- LionSat will demonstrate the future of satellite communication protocols